

Hydrogen as a Transportation Fuel



What is Hydrogen?

Hydrogen is the simplest, lightest, and most plentiful element in the universe. It is made up of one proton and one electron.

In its normal gaseous state, hydrogen is colorless, odorless, tasteless, non-toxic, and burns invisibly.

Where does Hydrogen come from?

Currently, most hydrogen is made from natural gas through a process known as reforming. Reforming separates hydrogen from hydrocarbons by adding heat. Hydrogen can also be produced from a variety of sources including water and biomass.

Is Hydrogen more dangerous than other fuels?

Hydrogen is not more dangerous than any other fuel. Hydrogen's hazards are usually managed easier than hydrocarbon fuels because hydrogen is lighter than air, and it burns upward and disperses.

Hydrogen can however, cause brittleness in some materials, including metals, and can generate electrostatic charges and sparks through flow or agitation.

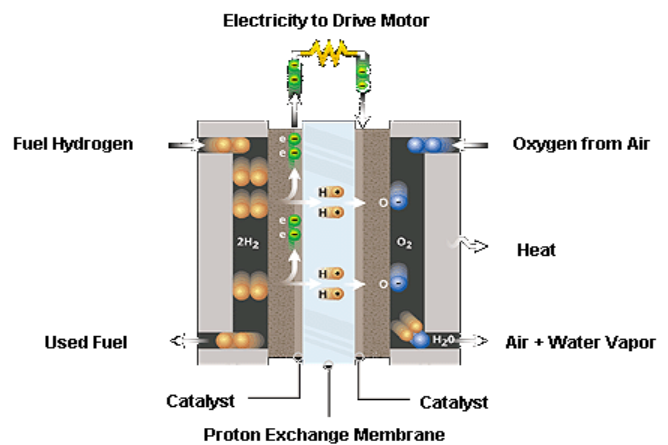
What is a fuel cell?

Fuel cells generate electricity from a catalyst-facilitated chemical reaction between hydrogen and oxygen ions in a cell. Several cells combined make up a fuel cell stack. Fuel cell systems have relatively few moving parts, and their only byproducts are water and heat when pure hydrogen is used as the fuel.

A fuel cell converts the chemical energy of a fuel directly into electricity without any intermediate thermal or mechanical processes. The electrical

energy can be used to do useful work directly while the heat is either wasted or used for other purposes.

A fuel cell stack requires fuel, oxidant, and coolant in order to operate. The gases must be humidified



and the coolant temperature must be controlled. To achieve this, the fuel cell stack must be surrounded by a fuel system, fuel delivery system, air system, stack cooling system and humidification system.

Fuel Cell Vehicles

From 2000 to 2005, 65 light duty fuel cell vehicles were placed in California and traveled more than 220,000 miles on California's roads and highways. These cars are still being tested and are available to a few fleets and consumers.

Fuel cell buses are being tested at SunLine Transit in Thousand Palms, Alameda-Contra Costa Transit (AC Transit), and Santa Clara Valley Transportation Authority (Santa Clara VTA). The buses began operation in 2005.

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In addition, buses are being tested at Sacramento Municipal Utility District and University of California at Davis.

Internal Combustion Engines

Getting an internal combustion engine to run on hydrogen is not difficult. The challenge is getting an internal combustion engine to run well on hydrogen. The U.S. Department of Energy (DOE) tested four internal combustion vehicles using hydrogen: a Dodge Ram van and a Ford F-150 with engines designed for compressed natural gas, a Ford F-150 with a gasoline



*Hydrogen Engine of HICE Bus
Photo courtesy of SunLine Transit Agency*

engine that was modified to run on a hydrogen/natural gas blend, and a Mercedes van with a gasoline engine modified to run on pure hydrogen. The tests showed the hydrogen lowered emissions and increased fuel economy (as compared to the engine on natural gas or gasoline alone).

Ford Motor Company has developed an internal combustion engine optimized to burn hydrogen instead of gasoline. The engine can reach an overall efficiency of about 38 percent, about 25 percent more fuel-efficient than a typical gasoline

engine with nearly zero emissions. The engine is based on Ford's 2.3 liter engine used in the Ford



*Hydrogen Hybrid-Electric Bus
Photo courtesy of SunLine Transit Agency*

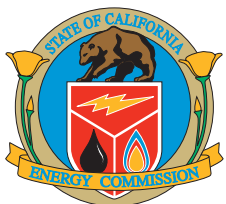
Ranger. Supercharging allows the engine to deliver the same power as its gasoline counterpart. Sunline Transit operates a hydrogen hybrid bus in revenue service. This bus has performed well and receives better fuel economy than diesel buses.

The Future of Hydrogen Vehicles

Possible hydrogen vehicles in the future may be:

- Vehicles with internal combustion engines using pure hydrogen, or using a mix of hydrogen and natural gas.
- Vehicles with fuel cells that use hydrogen that's either produced on-board by converting liquid fuels (gasoline, ethanol, or methanol) to hydrogen, or by using direct hydrogen that has been generated off-board and stored on the vehicle in compressed or liquid form.

Header photographs courtesy of the California Fuel Cell Partnership and Sunline Transit Agency.



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